

Improving sleep and cognition by hypnotic suggestion in the elderly[☆]



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ABSTRACT

Sleep quality markedly declines across the human lifespan. Particularly the amount of slow-wave sleep (SWS) decreases with age and this decrease is paralleled by a loss of cognitive functioning in the elderly. Here we show in healthy elderly females that the amount of SWS can be extended by a hypnotic suggestion "to sleep deeper" before sleep. In a placebo-controlled cross-over design, participants listened to hypnotic suggestions or a control tape before a midday nap while high density electroencephalography was recorded. After the hypnotic suggestion, we observed a 57% increase in SWS in females suggestible to hypnosis as compared to the control condition. Furthermore, left frontal slow-wave activity (SWA), characteristic for SWS, was significantly increased, followed by a significant improvement in prefrontal cognitive functioning after sleep. Our results suggest that hypnotic suggestions might be a successful alternative for widely-used sleep-enhancing medication to extend SWS and improve cognition in the elderly.

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1. Introduction

Sleep is vital for our health and well-being, and particularly slow-wave sleep (SWS) has been proven critical for restoration and optimal cognitive brain functioning (Finelli et al., 2001; Van Der Werf et al., 2009). In the elderly, sleep quality is typically strongly reduced and accompanied by an increased rate of clinically relevant sleep disturbances as well as extensive use of sleep-inducing medication (Crowley, 2011; Foley et al., 1995). In particular, SWS continuously decreases across the human life span, possibly reflecting the loss of synaptic density and neural functioning (Mander et al., 2013). SWS is strongly reduced in aging related disorders like mild cognitive dementia and associated with cortical thinning and prefrontal cortical atrophy (Mander et al., 2013; Sanchez-Espinosa et al., 2014). Furthermore, reduced sleep quality and sleep fragmentation in non-demented elderly participants are reliable predictors for later cognitive decline, increased amyloid beta disposition and development of Alzheimer's disease after several years (Keage et al., 2012; Lim et al., 2013; see Pace-schott

and Spencer, 2014 for a review). Frequently prescribed sleep-inducing drugs typically hinder the occurrence of SWS, loose their efficacy during long-term treatment, have adverse side effects and often a high risk of addiction (Hajak and Rütger, 2006; Riemann and Perlis, 2009). Therefore, the development of efficient and risk-free approaches to improve sleep and particularly SWS in the elderly is highly needed.

While the sleep-disturbing effects of negative thoughts, stress, and rumination are widely accepted (Saper et al., 2005; Van Reeth, 2000), research on the possibility of positively influencing sleep by psychological interventions is rather scarce. A reason might be the observation that cognitively "wanting" to improve sleep quality typically fails or can even be counterproductive (Ansfield et al., 1996). Thus, subconscious influences might prove more effective in this regard, which could be exerted under the state of hypnosis. Hypnosis was very recently defined as "a state of consciousness involving focused attention and reduced peripheral awareness characterized by an enhanced capacity for response to suggestion" (Elkins et al., 2015, p. 6). Importantly, during the state of hypnosis, suggestible subjects respond more easily to hypnotic suggestions. These are statements given during induction or afterwards, intended to change or influence behavior. They can include e.g., decrease of pain, motor paralysis or posthypnotic amnesia, and recent cognitive neuroscience research has successfully demonstrated effects of these suggestions on underlying brain activation using objective neuroimaging methods (Cojan et al., 2013; see

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Kihlstrom, 2013 for a review). In therapeutic contexts, hypnosis has been proven an effective tool in reducing pain, anxiety and stress related disorders (Flammer and Bongartz, 2003), and several studies provide evidence for a beneficial effect of hypnosis on sleep disturbances and insomnias (Borkovec and Fowles, 1972; Schlarb, 2005; Stanton, 1989). For instance, a randomized controlled trial study demonstrated a substantial improvement in self-rated sleep quality in post-menopausal women after clinical hypnosis intervention. This improvement even continued as indicated by the 12 week follow-up test (Elkins et al., 2013). Very recently, we have shown that listening to a hypnotic suggestion before sleep strongly extends the amount of SWS and slow-wave activity (SWA, 0.5–4.5 Hz) in young healthy females suggestible to hypnosis (Cordi et al., 2014). SWA is regarded as the hallmark oscillatory brain activity characterizing SWS and has been functionally related to processes of brain plasticity and synaptic density (Huber et al., 2004). Control experiments confirmed that the type of hypnotic suggestions was critical for the beneficial effect on SWS and excluded alternative explanation like general relaxation and demand characteristics. Interestingly, less suggestible females did not benefit from the hypnotic suggestions, even when asked to simulate the effects of a hypnotized person (see Cordi et al., 2014). However, it remains an open question whether these results are robust and generalizable to elderly participants. In addition, it remains elusive whether hypnosis-induced increases in SWS and frontal SWA result in an improvement in cognitive functions. We predicted that SWS and SWA will increase after hypnotic suggestions in highly suggestible elderly females. Further, particularly in the elderly, prefrontal SWA has been recently associated with age-related prefrontal brain atrophy and cognitive functions (Mander et al., 2013). Thus, we expected performance in tasks recruiting frontal areas to improve after SWA increases.

2. Methods

2.1. Participants

Forty-two healthy, German-speaking elderly females with a mean age (\pm standard deviation [SD]) of 67.10 ± 4.26 years (age range 60–82) took part in the experiment. Only females were recruited to avoid known gender effects on sleep architecture and suggestibility (Carrier et al., 2001; Fukuda et al., 1999; Page and Green, 2007). One subject was excluded due to lacking sleep, two others did not keep caffeine restriction in one of the two experimental sessions. A prior power calculation based on our previously published study in young females (Cordi et al., 2014) revealed an optimal sample size of $n=38$ participants to detect an effect size of $f=0.33$ ($\eta_p^2 \approx 0.1$) with a probability of $> 95\%$ (assumed correlation among repeated measures $\rho=0.4$, power calculation performed by G*Power3 (Erdfeulder et al., 1996)). For the final sample of 39 subjects included in the analysis, suggestibility to hypnosis was scaled according to the Harvard Group Scale of Hypnotic Susceptibility (HGSHS) prior to the experiment (cut-off score for high suggestibility: HGSHS ≥ 7) (Bongartz, 1985). In this sample, nineteen women were highly suggestible (HS) (mean age 66.42 ± 4.10 years; HGSHS: $7.95 \pm .20$ SEM) and 20 women were low suggestible (LS) (mean age 67.70 ± 4.66 years; HGSHS: $4.03 \pm .44$). The two experimental groups did not differ in age ($p > .30$). Due to technical problems, memory performance data (paired-associates learning task) are missing for three subjects (2 HS, 1 LS). On average, participants reported normal sleep (Pittsburgh Sleep Quality Index, PSQI mean \pm SD: 5.33 ± 2.60 (Buysse et al., 1989)). To assure general health of the subjects, a history of neurological or psychiatric disorders, intake of pharmacological sleep medication more than twice a month and acute physical

disorders were defined as exclusion criteria. Participants were asked to refrain from caffeine and alcohol during the test day and to get up before 8 a.m.. Participants gave their written consent to take part in the study and were paid 140 Swiss francs for participation. The Ethics Committee of the University of Zurich approved the study.

2.2. Materials

Audio files. Participants either listened to a tape including hypnotic suggestions to sleep deeply or a control tape, both taken from Cordi et al. (2014). While hypnotic suggestions were given with a calming, soft voice and slow rate of speaking, the control text was as neutral as possible with neither activating nor calming words and an everyday intonation. Both texts are publicly available (<http://www.psychologie.uzh.ch/fachrichtungen/allgpsy/biopsy/links.html>). Participants were allowed to fall asleep during or after the tape, and were, in all conditions, constantly awakened after 90 min in bed (see Fig. 1, for the procedure).

2.2.1. Memory measures

Memory functions were tested before and after the nap. In the semantic verbal fluency test (SVT), subjects were asked to generate as many words of a given category as possible within 2 min. The number of acceptable, listed words was taken as measure of retrieval performance of long term memory storage (Lezak, 1995). This test has proven to be age-sensitive (Haugrud et al., 2010) and dependent on frontal functioning as shown in several lesion studies (Miceli et al., 1970). For analyses, percentage of postsleep performance was computed relative to presleep performance. Parallel versions were used in a randomized order (four categories (animals, hobbies, fruits, professions) for pre- and postsleep measures in both sessions were used). As percentage of improvement across the nap strongly correlated with SVT performance before sleep ($r(45) = -.71$, $p < .001$ for hypnosis, $r(45) = -.52$, $p < .001$ for control), presleep performance was regressed out and the analyses were run on the adjusted values. Second, an episodic word pair learning task (Rasch et al., 2006) was conducted. Hippocampus-dependent declarative memory consolidation of word-pairs is known to depend on early, SWS rich sleep (Plihal and Born, 1997; Rasch and Born, 2013). Subjects had to learn a list of 30 semantically related word pairs adopted from Rasch et al. (2006) and also used in Cordi et al. (2014), although presented more slowly (see Table S4). After a fixation cross, the first word appeared for 2 s, followed by a 500 ms blank interval and the second word, which was presented for 2 s. A blank interval of 500 ms preceded the next fixation cross. The words were presented in black font on white screen via E-Prime (Psychology Software Distribution, High Sittenham, UK). Each word pair was presented only once. Cued recall was tested immediately after learning and again after the nap. After the first word was displayed, participants were asked to come up with the corresponding second word aloud. Response time was not restricted. The order of the word pairs during recall differed from learning phase. Performance was measured as percentage of words recalled at postsleep retrieval relative to the number of word pairs remembered immediately after learning. Also in the declarative memory test, parallel versions were used (parallel word lists, see Table S4).

2.2.2. Psychomotor vigilance test

After sleep, the psychomotor vigilance test (PVT) was conducted to overcome sleep inertia and measure the effects of sleepiness on vigilance (Dinges and Powell, 1985). A millisecond counter appeared on the screen at random intervals and subjects were asked to press the space key as soon as they recognized the counter counting upwards. The reaction time was displayed in ms for 1 s after the keypress.

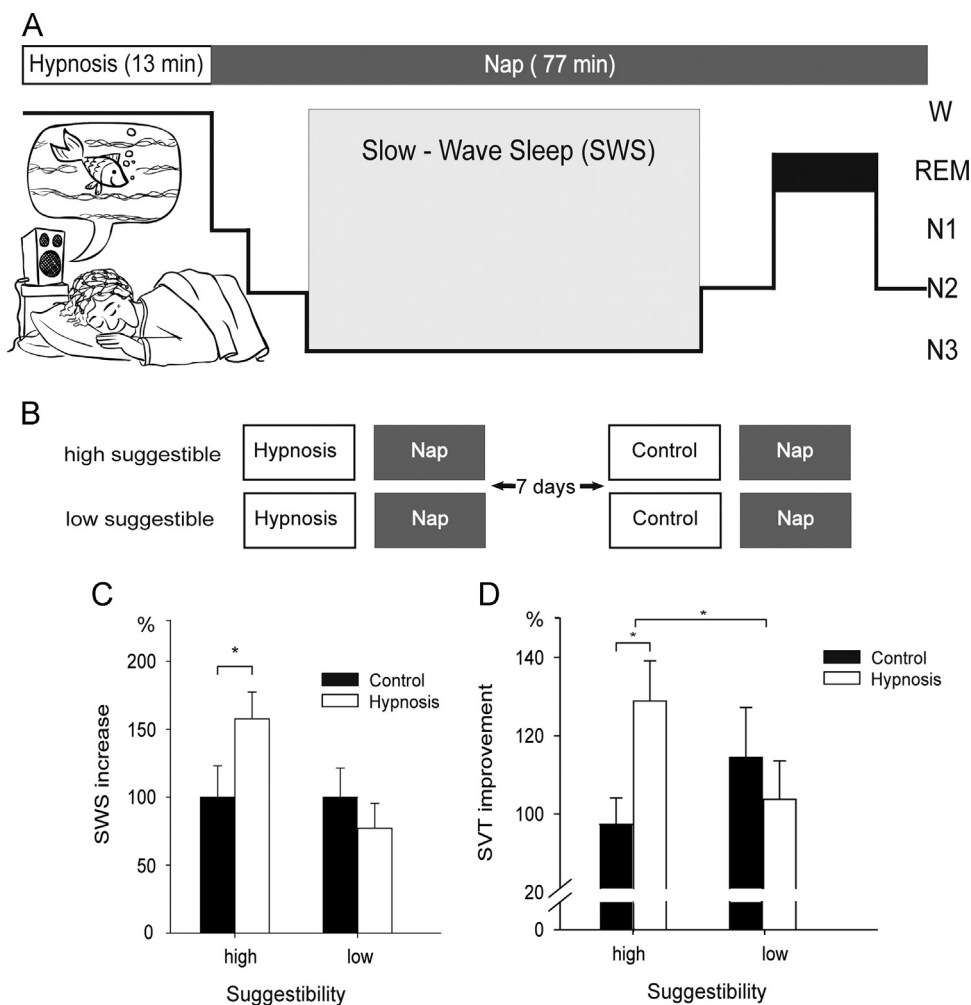


Fig. 1. Overview of the session procedure and the main findings. Note: (a) Subjects listened to the hypnotic suggestions (a fish swimming deeper and deeper in the sea) or a control text in a randomized order while lying in bed. Immediately afterwards they were allowed to fall asleep and were awakened after a total of 90 min. (b) Both sessions of the within-subjects design were spaced one week apart. High ($n=19$) and low ($n=20$) suggestible elderly females (mean age 67.08 ± 4.39 years) participated in the study. (c) Hypnotic suggestions “to sleep deeper” significantly increased the amount of SWS in high suggestible elderly females. SWS in low suggestible females was not affected. Percentages of SWS (with SWS amounts in the control naps set to 100%) are indicated. (d) Hypnosis-induced increases in SWS resulted in improved prefrontal memory performance (verbal fluency task) in high suggestible elderly females after the nap. Improvement across the nap is indicated, with presleep performance set to 100%. *: $p < .05$.

2.2.3. Polysomnographic recordings

To measure sleep, electromyographic (EMG), electrocardiographic (ECG), and electroencephalographic (EEG) electrodes were attached. EEG was recorded using a high-density 128-channel Geodesic Sensor Net (Electrical Geodesics, Eugene, OR) with a sampling rate of 500 Hz. Impedances were kept below 100 k Ω . Electrodes were initially referenced against the Cz channel, however re-referenced during preprocessing to both mastoids. Data was preprocessed with Brain Vision Analyzer 2.0 (Brain Products, Gilching, Germany), filtering the data according to the standard filter settings suggested by the American Association of Sleep Manual (AASM), e.g., 0.3–35 Hz. Two independent sleep scorers blind to condition visually scored sleep in 30 s periods based on derivations F4, C4, O4, HEOG, VEOG, and EMG. In case of disagreement a third expert was consulted, who was also blind to experimental condition. Stages 1–3, REM sleep, and wake after sleep onset (WASO) were scored.

Power in slow-wave activity (SWA, 0.5–4.5 Hz) bands was computed for about 8 s epochs by a Fast Fourier Transforms (FFT) (using a Hamming window of 10% and a 0.2 Hz resolution) after excluding bad intervals marked by amplitudes exceeding power differences of 500 μ V. Relative SWA with total power set to 100%

was computed for the analyses. We focused on frontal SWA as this measure has been shown to be most relevant for sleep-related memory consolidation and cognitive functioning, particularly in the elderly (Rasch and Born, 2013; Mander et al., 2013). As particularly associations between left low frequency power and cognitive performance were demonstrated in older adults previously (Anderson and Horne, 2003), we included hemisphere as a factor. The electrodes were grouped to two topographical regions: right frontal (electrodes 1–5, 8–10, 14, 116–118, 124, 121–123) and left frontal (electrodes 12, 17, 19–26, 28, 32–34, 38) region (see Fig. S1). Frontal hemisphere (left, right) was used as factor in the ANOVA. Due to high correlations between SWA power in experimental and adaptation nights ($r(37)=.62$, $p < .001$), SWA amount of the adaptation night was partialled out of SWA in experimental sessions and the adjusted means were considered for analysis.

2.3. Design and procedure

Participants had an adaptation nap and two experimental nap sessions in the sleep laboratory. The experimental sessions were spaced 7 days apart, to control for an individual week schedule. Each week before both experimental sessions, subjects kept a

sleep diary. All subjects were explicitly informed about the purpose to deepen their sleep through hypnosis. All sessions started around 1 p.m. with the attachment of 128 EEG electrodes, EMG and ECG electrodes, which recorded the 90 min of nap including listening to the text before sleep in the experimental sessions. Before going to bed, participants performed two declarative memory tasks. When participants were lying in bed, lights were turned off and the 13 min tape record was started. Either the tape including hypnotic suggestions or the control tape was played over bedside speakers, in a randomized and balanced order according to a placebo-controlled cross-over design. After awakening, participants answered a subjective sleep quality questionnaire (Görmelmeier, 2011) and conducted the PVT. Then they recalled the 30 word pairs before repeating the semantic verbal fluency test. At the end of the second experimental session, participants filled out a general post experimental questionnaire.

2.3.1. Statistical analyses

Sleep was analyzed using a repeated measures analysis of variance (ANOVA) using the repeated factor “text” (hypnosis vs. control) and the between subject factor “suggestibility” (high vs. low). For EEG power analyses, the factor “frontal hemisphere” (right, left) was additionally used. According to Fisher’s protected LSD test, significant main effects and interactions were further explored using paired sample *t*-tests. Associations were explored with Pearson correlations. Using age as a covariate did not change the results. Means \pm standard error of the mean (SEM) are shown unless otherwise indicated. The level of significance was set to $p = .05$.

3. Results

3.1. Influence of the hypnotic suggestion on subsequent SWS

Thirty-nine healthy elderly females (mean age 67.08 ± 4.39 years \pm standard deviation [*SD*]) were included in the analysis. Prior to the experiment, all participants were classified as highly ($n = 19$) vs. low suggestible ($n = 20$) according to the Harvard Group Scale of Hypnotic Susceptibility (HGSHS) (Bongartz, 1985). After an adaptation nap in the sleep laboratory, all participants came for two experimental midday naps of 90 min to the sleep laboratory. The elderly females listened either to the hypnosis or the control tape in a counterbalanced order for 13 min while lying in bed (see Fig. 1A and B, for a summary of the procedure). The hypnosis tape consisted of a standard hypnosis induction procedure, followed by hypnotic suggestions to sleep deeper (i.e., a fish swimming deeper and deeper in the sea, see methods). The control text was a neutral text on mineral deposits. Memory functions were tested before and after the nap and sleep was recorded using high density EEG and standard polysomnography.

As predicted, listening to hypnotic suggestions “to sleep deeper” before sleep strongly extended the amount of time spent in deep sleep in elderly females suggestible to hypnosis. Importantly, the hypnotic suggestion before sleep increased the amount of SWS to $157.69 \pm 19.66\%$, with the amount of SWS after the control text set to 100% (see Fig. 1C and Table 1). In contrast, females not suggestible to hypnosis did not benefit from the intervention (repeated measures ANOVA with the factors suggestibility (high vs. low) and condition (hypnosis vs. control text), $F(1, 37) = 5.88$, $p = .020$, $\eta^2 = 0.14$). Planned pairwise comparisons confirmed that after listening to the hypnotic tape, highly suggestible females spent on average $27.48 \pm 3.43\%$ (20.58 ± 3.01 min) of their time in bed in SWS as compared to only $17.43 \pm 4.03\%$ SWS (11.84 ± 2.92 min) after listening to the control tape ($t(18) = 2.27$, $p = .036$, $t(18) = 2.86$, $p = .010$ for SWS % and min, respectively). In addition,

Table 1

SWS amount in older adults and young adults.

	Older adults		Younger adults	
	Hypnosis	Control	Hypnosis	Control
% SWS (with control condition set to 100%)				
HS	157.7 \pm 19.7%	100.0 \pm 23.1%*	181.2 \pm 29.0%	100.0 \pm 25.9%*
LS	77.1 \pm 18.4%	100.0 \pm 21.5%	65.7 \pm 13.8%	100.0 \pm 16.6%*
% SWS (of total time in bed)				
HS	27.5 \pm 3.4%	17.4 \pm 4.0%*	30.6 \pm 4.9%	16.9 \pm 4.4%*
LS	18.8 \pm 4.5%	24.4 \pm 5.2%	18.5 \pm 3.9%	28.1 \pm 4.7%*
Minutes spent in SWS				
HS	20.6 \pm 3.0 min	11.8 \pm 2.9 min*	23.4 \pm 4.3 min	14.1 \pm 3.6 min*
LS	12.3 \pm 3.2 min	18.9 \pm 4.4 min	14.6 \pm 3.3 min	24.3 \pm 4.2 min*
SWS latency				
HS	15.1 \pm 3.6 min	27.7 \pm 5.9 min*	12.8 \pm 0.9 min	27.9 \pm 6.8 min*
LS	25.6 \pm 5.3 min	21.6 \pm 5.4 min	24.6 \pm 6.8 min	18.0 \pm 5.1 min
SWA Power (left frontal) in % Ptot, with control condition set to 100%				
HS	105.0 \pm 2.6%	100.0 \pm 2.5%*	105.3 \pm 9.4%	100.0 \pm 9.0%*
LS	98.1 \pm 2.7%	100.0 \pm 2.1%	99.5 \pm 6.7%	100.0 \pm 9.4%

Note. Values are means \pm SEM. %SWS: %SWS in the control condition set to 100%. HS=highly suggestible, LS=low suggestible. Ptot (percent of total power): relative SWA Power with total power set to 100%. SWA Power: relative SWA Power with control condition set to 100% (adjusted values for older adults). Average time in bed was 89.5 \pm .15 min in older adults and 92.9 \pm .63 min in younger adults and did not differ between conditions (both $p > .09$).

*: $p \leq .05$ in planned pairwise comparisons.

highly suggestible females reached SWS significantly earlier after hypnotic suggestions (15.05 ± 3.61 min) than after the control text (27.66 ± 5.88 min; $F(1, 37) = 4.34$, $p = .044$, $\eta^2 = 0.11$; $t(18) = 2.23$, $p = .039$, see Table 1 and S1). In low suggestible participants, the amount of SWS and SWS latency did not differ between conditions (both $p > .30$). Furthermore, we observed no effects of hypnotic suggestions on any other sleep stage (all $p > .40$, Table S1). Average sleep latencies did also not differ between hypnosis and control conditions, neither for highly suggestible (21.71 ± 4.60 vs. 18.97 ± 4.44 min, $t(18) = .65$, $p = .52$) nor for low suggestible participants (16.75 ± 2.33 vs. 12.70 ± 2.94 min, $t(19) = 1.77$, $p = .092$). Please note that sleep latencies were on average longer (see also Table S1) than the duration of the audio tapes (13 min), excluding that our reported results might be explained by falling asleep during the listening period.

3.2. Influence of the hypnotic suggestion on slow-wave activity during sleep

In accordance with the benefits on SWS, we observed a significant increase in prefrontal SWA power after hypnotic suggestions, which was particularly pronounced in left prefrontal brain areas (ANOVA with the factors suggestibility (high vs. low), condition (hypnosis vs. control) and hemisphere (left vs. right) $F(1, 37) = 6.74$, $p = .013$, $\eta^2 = .15$; substantiated by a statistical trend in the two-way interaction suggestibility* condition $F(1, 37) = 2.90$, $p = .097$, $\eta^2 = .07$). Planned pairwise comparisons confirmed that left prefrontal SWA power in suggestible participants was increased in the hypnosis as compared to the control condition ($104.99 \pm 2.62\%$, with the control condition set to 100%, ($t(18) = 2.17$, $p = .044$, see Fig. 2B and Table 1).

3.3. Influence of the hypnotic suggestion on prefrontal cognitive functioning

In a last step, we tested whether the robust hypnosis-induced increases in SWS and prefrontal SWA are reflected in cognitive benefits in tasks recruiting prefrontal areas in the elderly

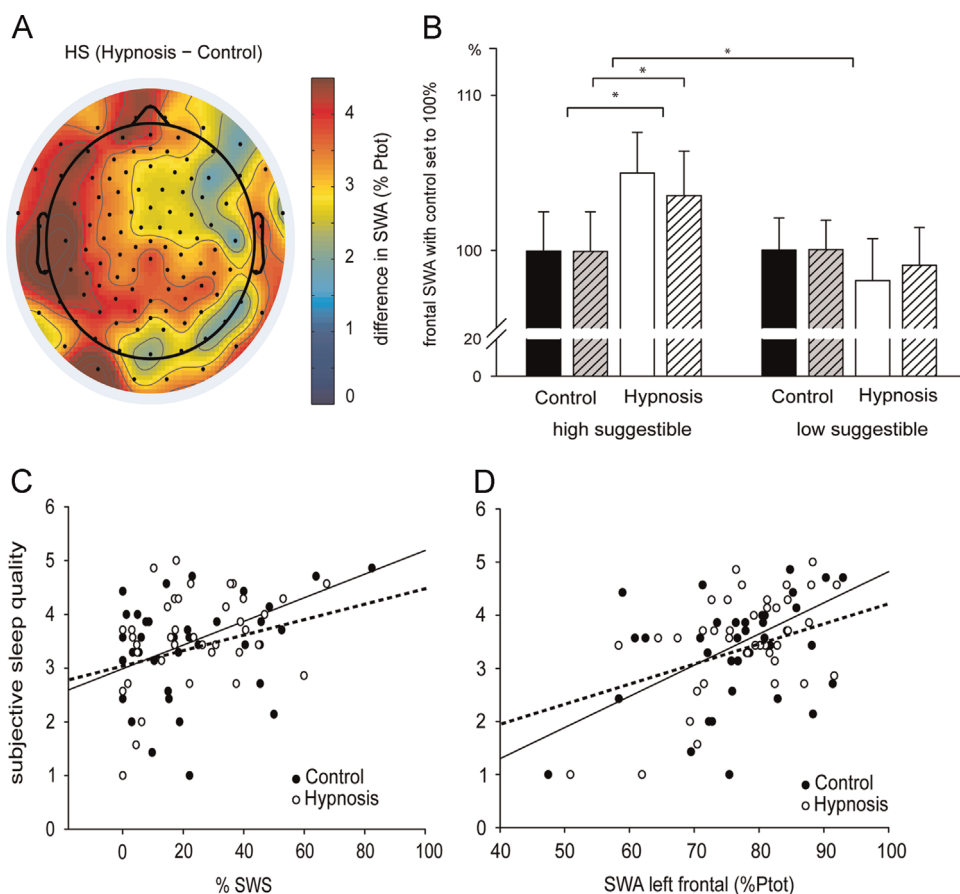


Fig. 2. Results on SWS and correlations between objective and subjective sleep measures. Note: Highly suggestible elderly females (HS) display a large-scale increase in relative NREM SWS (Ptot=Power in the SWS band with total power set to 100%) after hypnosis versus control condition, preferentially in the left hemisphere. Results are indicated for all single electrodes (a) and for combined frontal derivations (b, for region definition see Fig. S1). Hatched bars indicate right frontal area, uniform bars represent left frontal side. The white bars display hypnosis condition, darker bars the control condition. (c) Subjective ratings of sleep quality were correlated with % SWS separately for conditions (black dots represent data from control condition, white dots from hypnosis) and (d) SWA in left frontal derivations. Dotted lines are regression lines of the hypnosis condition. Error bars represent standard errors of the mean. *: $p < .05$.

participants. Importantly, the semantic verbal fluency task (SVT) is sensitive for prefrontal cortex functions and for healthy aging (Haugrud et al., 2010; Miceli et al., 1981; Ramier and Hécaen, 1970). Suggestible participants exhibited a significant improvement in this task after hypnosis-induced increases in SWS, whereas no effects were observed for low suggestible females (interaction suggestibility * condition; $F(1,37)=4.24$, $p=.047$, $\eta^2=.10$). Planned pairwise comparisons confirmed that suggestible elderly females exhibited increased performance in the SVT task ($128.87 \pm 10.22\%$, with pre-sleep performance set to 100%) as compared to pre-sleep performance ($t(18)=2.83$, $p=.011$) as well as compared to the performance change across the control nap ($97.33 \pm 6.74\%$, $t(18)=2.69$, $p=.015$, see Fig. 1D and Table S2). These changes were not observed in low suggestible participants (all $p > .50$). Similarly, hippocampus-dependent declarative memory consolidation of word-pairs known to depend on early, SWS rich sleep (Plihal and Born, 1997) descriptively reflected the pattern of hypnosis-induced SWS changes. However, effects in consolidation reached only a statistical trend ($F(1, 34)=3.24$, $p=.081$, $\eta^2=.09$, see Table S3). Generally, our results on cognitive measures were not confounded by differences in vigilance as we observed no significant influences of SWS / SWA changes in the psychomotor vigilance test (PVT) tested directly after the nap ($p > .80$ for highly and low suggestible subjects). Overall, the subjective sleep quality ratings were significantly associated with percentage of SWS and frontal left SWA power in both groups and both conditions, suggesting that increased SWS and SWA generally

contribute to subjective feelings of better sleep quality (%SWS: $r=.42$, $p=.008$ and $r=.31$, $p=.059$; frontal left SWA: $r=.55$, $p < .001$ and $r=.38$, $p=.020$; for hypnosis and control condition, respectively, see Figs. 2C and D).

3.4. Comparison between younger and older adults

Using a basically identical experimental design as reported here, we have previously published the finding that listening to hypnotic suggestions before sleep extends SWS and increases SWA in younger female participants (aged 23.27 ± 3.17 years, (see Cordi et al., 2014)). In this prior work we have already experimentally confirmed that the beneficial effect of hypnotic suggestions on SWS critically depends on the type of the hypnotic suggestion and successfully excluded alternative explanations, i.e., generally relaxing effect of the hypnosis tape or demand characteristics. Therefore we directly compared our current findings in elderly females to the hypnosis-induced increases in SWS in young adults. The result pattern in old and young females was basically identical and robust, revealing strong hypnosis-induced increases in SWS in both suggestible young ($181.16 \pm 28.95\%$) as well as elderly females ($157.69 \pm 19.66\%$, with SWS amount after the control text set to 100%). No or even opposite effects were observed for low suggestible participants (see Table 1). Combining relative SWS amounts (with %SWS in the control condition set to 100%) from both data sets revealed a highly significant interaction between suggestibility (high vs. low) and condition (hypnosis vs. control)

$F(1,64)=18.10$, $p < .001$, $\eta^2=.22$) indicating the robustness of the benefits of hypnotic suggestions on SWS. Comparable effects were observed for percentage of SWS, minutes spent in SWS and SWS latency (all $p < 0.002$, see Table 1). Similarly, prefrontal SWA was strongly influenced by the experimental condition and suggestibility ($F(1,63)=5.23$, $p=.026$, $\eta^2=.08$, see Table 1). Importantly, listening to hypnotic suggestions before sleep extended the amount of sleep and increased SWA independently of age, as indicated by a complete lack of interaction effects with age (all $p > .60$).

4. Discussion

In confirmation of our hypothesis, listening to a hypnotic suggestion “to sleep deeper” significantly extended the amount of SWS during a midday nap in healthy elderly females. In addition, left prefrontal SWA was significantly increased during sleep after listening to the hypnosis and performance in a prefrontal-dependent verbal fluency task was significantly improved. The benefits of hypnosis on sleep in elderly suggestible females were highly comparable to the effects of hypnotic suggestion on sleep in younger suggestible females as reported previously (Cordi et al., 2014). Thus, the usage of hypnotic suggestion to extend SWS in suggestible females appears to be robust and largely age-independent.

It might be argued that the beneficial effects of hypnotic suggestions on SWS are unspecific and rather due to the relaxing nature of the hypnotic text or the expectations of the participants of being hypnotized. We cannot fully rule out this alternative interpretation of our results in elderly subjects, which represents a clear limitation of our current study. However, we have already safely excluded these interpretations in several control experiments in young females (see Cordi et al., 2014): Young suggestible females expecting that the hypnosis will extend their SWS listened to same hypnotic vs. control text as used in the current experiment. However, the hypnotic suggestion in this group was altered now suggesting “to sleep shallower” (i.e., a boat resting on the surface). In spite of the identical generally relaxing property and hypnosis induction of this version of the hypnosis tape, we observed no significant increase in SWS in the hypnosis condition. An additional control experiment excluded that mere expectancies or demand characteristics might explain our results. Thus, these control studies showed that the use of hypnosis and the content of the hypnotic suggestion are critical for the beneficial effect of hypnosis on SWS. Although we thereby safely excluded general relaxation effects as confounding factors in younger adults, we did not include such a control condition in the current sample. Future studies should rule out relaxation effects as opposed to the beneficial effects of hypnotic suggestions on SWS also in older adults by using either relaxation control tapes or other techniques (e.g., progressive muscle relaxation etc.). Interestingly, low suggestibles did not benefit from the hypnotic suggestions, but rather showed a descriptive tendency of reduced SWS after listening to the hypnotic suggestion, similar to our results in younger participants. Opposite effects of hypnotic suggestions in low suggestible have been reported in previous experimental studies (Jones and Spanos, 1982; Oakley and Halligan, 2013), raising the possibility that low suggestible participants are in fact (consciously or subconsciously) counteracting the given suggestions. As asking subjects to “simulate” the benefits of hypnotic suggestions on SWS can neither elicit the effect in low suggestible females (see Cordi et al., 2014), it remains an open question how elderly, low suggestible females could also benefit from hypnosis as a tool for SWS extension.

Generally, the amount of sleep and particularly SWS strongly decreases across the lifespan, and the decrease of SWS is

paralleled by a loss of cognitive functions. While hypnotic suggestions might prove a relevant alternative to widely-utilized sleep medication, here we also show that the increase in SWS by hypnotic suggestions leads to significant improvement of prefrontal cognitive functions after the nap. More specifically, in the hypnosis condition we observed a 28% pre- to postsleep improvement in the verbal fluency task, which is assumed to strongly rely on the prefrontal cortex. This change was significantly higher as compared to the change observed in the control condition. Furthermore, a similar improving trend for memory consolidation the hypnosis-induced increase in SWS and SWA was also found. This pattern is well in line with the model proposed by Mander et al. (2013) that low prefrontal SWA is associated with aging-related prefrontal atrophy and significantly contributes to prefrontal cognitive functions. Finally, the reported positive association between SWS, SWA and subjectively rated sleep quality confirms their contribution to the feeling of being rested and satisfied with one's sleep.

While our study clearly shows that hypnotic suggestions are effective in extending SWS as well as cognitive functions in the elderly, there are limitations of our study. First, we only used female participants to control for possible increases in variance by gender differences in sleep architecture and hypnotic suggestibility. However, future studies will need to replicate the beneficial effects of hypnotic suggestion on SWS in men. Second, we examined only a midday nap, and it will be highly important to extend our findings to nighttime sleep as well as sleep disturbances in the elderly.

Taken together, our results indicate that psychological interventions using hypnotic suggestions are effective in improving sleep and SWS as well as cognitive functions in the elderly. Our results suggest that hypnotic suggestions might prove a successful alternative for widely-used sleep-enhancing medication to extend SWS and improve cognition in the elderly. They provide an important basis for future studies examining the benefits of hypnotic suggestions in patients with sleep disturbances as well their long-term benefits after repeated applications in every-day life.

Author contributions

B.R. and M.C. developed the study idea and designed the study. M.C. collected the data, S.H. and S.M. helped with the recruitment. B.R. and M.C. performed the data analysis. All authors contributed to data interpretation, manuscript drafting, and approved the final version for submission.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary Information

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.neuropsychologia.2015.02.001>.

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